ON THE RELATIONSHIP BETWEEN THE LITHOLOGY OF THE ABRASION AREA AND THE TRANSPORTED SEDIMENTS

By B. MOLNÁR

Geological Institute of the József Attila University, Szeged

The method based on the examination of heavy-mineral composition is taking a more and more important part in the study of the geology and hydrogeology of clastic sediments in Hungary, too; the data obtained in this way may considerably contribute to reach right conclusions on the hydrogeology and palaeohydrography of the respective area.

The catchement area of each river has its characteristic lithology, thus the lithological and mineralogical composition of the alluvia coming from this area in the course of the erosion will probably be characteristic of the catchment area. If heavy-mineral compositions of the alluvia of different rivers — as a factor characteristic of the genesis of the sediment — is known, we shall be able to distinguish their recent deposits from the older ones, to recognize their horizontal and vertical extension, to point out more precisely the former courses of the rivers: these examinations thus contribute to get a complete palaeohydrographical picture.

In Hungary, examinations of this kind may be of particular importance, scil., in the basins, the thickness of clastic, young, Tertiary and Quaternary strata is very considerable, and they consist of fluvial deposits, for the most part. Later on, one will be able to determine their origin, if, at first, the composition of the alluvia of recent rivers will be known, in order to draw conclusions concerning the origin of older deposits.

The above-mentioned possibility as well as the demands of Hungarian researchers working in this field have pressed for a detailed examination of this problem of the day, thus we have carried out heavy-mineral examinations on every important river of Hungary. We have examined how far the geology of the catchment area was reflected by the heavy-mineral composition, and, here and there, we have examined fossil fluvial sediments, too, in order to determine the genesis of the latter. Grain size distribution of each sample was determined, and the results plotted on grain-size-distribution graphs. (See grain-size-distribution graphs.) It was necessary because grain size distribution affects heavy-mineral composition, too. [14]

After the usual bromoform separation, heavy-mineral composition of the fraction 0,1 to 0,125 mm in diameter, or — if the sample contained but a little of this fraction, *i. e.* in the case of coarser and better sorted matters — that of the 0,1—0,2 mm fraction was determined. A table of the detailed results, grouped according to the genesis of the minerals, in the case of metamorphic minerals according to the succession of the zones of origin (crystalline schist zones) has been drawn up. (See Table).

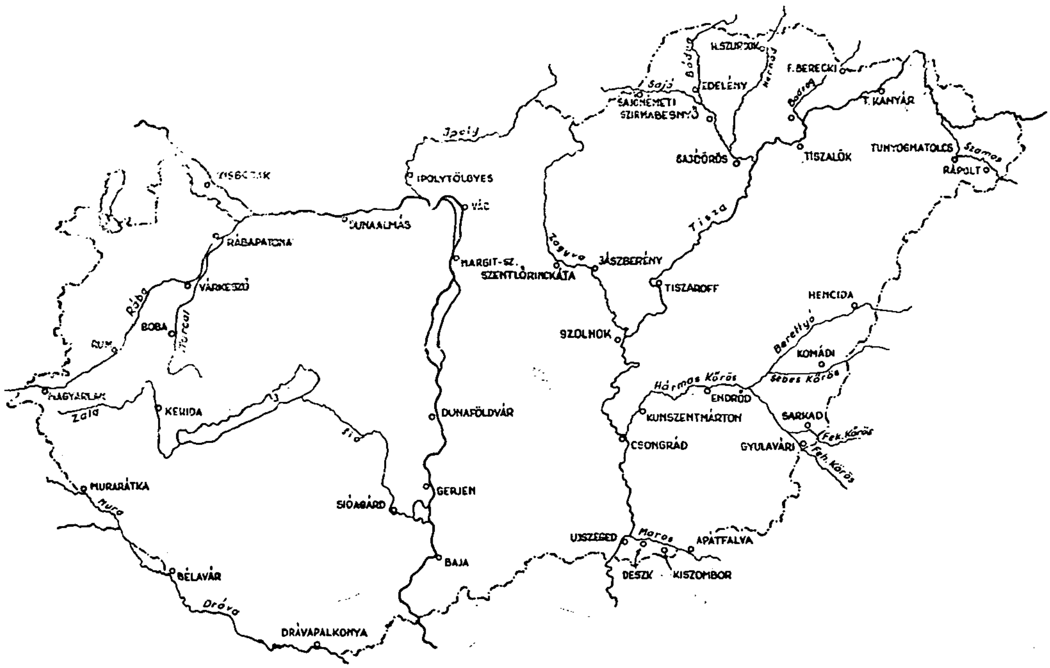

Fig. 1. Places of occurrence of the samples examined.

On the left-side of the Table we have indicated the rivers or the places of occurrence of the samples examined, respectively, while on the right-side the total quantity of the heavy-minerals to be found in the fraction examined, in proportion to that of the light minerals, as well as the fraction examined and the dominant grain diameter read of the grain-size-distribution graphs, in millimetres, are to be seen.

We have also graphically plotted the percentages of the dominant minerals characteristic of each river and catchment area, thus differences and changes taking place, in the case of rivers of some length, during their course are easily observable.

THE DANUBE REGION
(The Danube and its tributaries)

Among the *Danubian* alluvia, the first two samples were taken at Kisbodak, near the Austro—Czechoslovak border, and at the more distant Dunaalmás, respectively. The samples consist, for the most part, of fine-grained (0,1 to 0,2 mm) and, to a lesser degree, of medium-grained sand (*Fig. 2,* A). (As for

Serial number	PROVENANCE	Dominantly magmatic minerals											Dominantly metamorphic minerals														Other minerals					Total quantity of the heavy-minerals	Diameter of the fraction examined, in mm	Dominant grain diameter
		Hypersthene	Other rhombic pyroxenes	Monoclinic pyroxenes*	Darkbrown amphibole	Light brown amphibole	Magnetite	Olivine	Biotite	Apatite	Zircon	Volcanic glass	Chlorite	Tourmaline	Epidote	Zoisite	Rutile	Bluish green amphibole. (Hornblende)	Actinolite-tremolite	Anthophyllite	Topaz	Garnet	Staurolite	Cyanite	Andalusite	Glaucophane	Calcite-dolomite	Anhydrite	Limonite	Other micas	Weathered minerals			
1.	Duna (Kisbodak)	—	3,1	7,4	1,0	3,5	1,5	—	—	1,5	—	—	11,1	0,5	1,1	1,0	—	3,0	0,5	—	1,0	20,1	1,5	0,5	—	—	20,1	—	1,0	—	20,6	10,4	0,1–0,125	0,18
2.	Duna (Dunaalmás)	0,5	3,5	8,2	3,5	—	11,8	—	0,5	1,1	0,5	—	5,4	0,5	1,1	—	1,1	4,1	2,3	0,5	0,5	25,1	1,1	—	—	—	7,6	—	1,1	—	20,0	21,3	0,1–0,125	0,13
3.	Duna (Váctól É-ra)	8,8	1,1	5,6	7,8	0,5	6,1	—	—	1,1	—	—	3,9	1,6	1,1	—	—	3,9	0,5	1,1	—	31,5	1,6	1,6	—	—	2,3	—	—	0,5	19,4	17,3	0,1–0,125	0,34
4.	Duna (Margitsziget)	1,1	2,1	5,9	8,4	4,3	14,9	—	—	1,1	0,5	—	2,1	1,1	1,6	—	0,5	1,6	1,6	—	—	34,0	1,6	1,1	—	—	2,6	—	1,1	—	12,8	29,1	0,1–0,125	0,32
5.	Duna (Dunaföldvár)	0,5	1,1	5,9	10,7	4,8	4,8	—	—	0,5	—	—	7,5	0,5	1,1	—	—	5,3	1,6	—	—	26,2	1,1	1,1	—	—	4,3	—	1,6	—	21,4	10,9	0,1–0,125	0,17
6.	Duna (Gerjen)	—	4,3	9,0	2,1	6,4	6,4	—	—	1,1	0,5	—	9,0	2,1	1,6	0,5	—	6,4	1,6	0,5	—	16,0	1,6	1,6	—	—	3,2	—	1,6	—	24,5	11,5	0,1–0,125	0,21
7.	Duna (Baja)	0,5	3,7	5,3	1,1	4,2	2,7	—	—	1,6	—	—	16,5	0,5	1,6	0,5	—	11,2	2,7	0,5	—	16,0	1,1	2,1	—	—	3,7	—	1,6	—	22,9	3,9	0,1–0,125	0,18
8.	Rába (Magyarlak)	0,6	1,7	10,4	0,6	3,3	5,5	—	—	—	—	—	9,9	2,2	—	—	0,6	3,3	2,8	—	—	32,6	—	2,2	—	—	—	—	1,7	—	22,6	4,3	0,1–0,2	0,57
9.	Rába (Rum)	1,9	6,7	8,6	1,8	4,2	10,4	—	—	0,6	—	—	6,1	3,1	0,6	1,2	0,6	1,8	2,4	—	—	39,0	—	0,6	—	—	—	—	0,6	—	9,8	14,0	0,1–0,125	0,25
10.	Rába (Várkesző)	0,5	3,6	7,1	—	3,6	6,5	—	—	—	—	—	18,9	1,2	—	0,5	—	0,5	2,3	—	—	31,3	0,5	0,5	—	—	—	—	1,7	—	21,3	11,2	0,1–0,2	0,23
11.	Rába (Rábapatona)	—	2,8	6,1	0,5	3,8	8,2	—	—	2,2	—	—	8,8	1,1	0,6	0,6	1,7	2,8	1,7	—	—	39,6	1,1	0,6	—	—	—	—	1,7	—	17,1	6,7	0,1–0,2	1,30
12.	Marcal (Boba)	—	3,9	4,9	—	1,1	2,3	2,8	—	1,6	—	—	5,6	2,8	1,6	—	0,5	2,8	2,8	—	—	32,0	1,6	1,6	—	—	0,5	—	2,3	2,8	26,5	10,5	0,1–0,2	0,25
13.	Zala (Kehida)	—	2,6	7,4	2,0	2,7	9,4	—	—	3,4	—	—	15,4	2,0	2,0	2,7	0,7	1,3	2,7	0,7	—	21,4	0,7	0,7	—	—	8,7	—	1,3	—	12,2	6,5	0,1–0,125	0,20
14.	Sió (Sióagárd)	—	5,2	7,2	1,0	—	4,6	0,5	—	3,1	—	—	9,3	2,1	4,2	4,2	—	—	2,1	0,5	—	16,1	1,5	3,1	0,5	—	3,7	—	0,5	—	30,6	4,7	0,1–0,125	0,16
15.	Mura (Murarátka)	—	0,7	2,6	0,7	2,6	2,0	—	—	0,7	—	—	3,3	0,7	0,6	2,0	—	6,0	2,0	—	—	60,0	0,7	—	0,7	—	—	—	0,7	—	14,0	46,0	0,1–0,2	0,27
16.	Dráva (Bélavár)	—	3,6	6,6	1,0	2,6	6,6	—	—	2,1	—	—	5,1	8,7	2,1	1,5	0,5	7,6	1,5	—	—	35,8	0,5	1,0	—	—	1,5	—	0,5	—	16,2	25,9	0,1–0,125	0,18
17.	Dráva (Drávapalkonya)	—	3,7	1,1	0,5	3,2	3,2	—	—	0,5	—	—	19,1	0,5	—	1,6	1,1	3,7	2,6	—	—	19,0	0,5	0,5	—	—	13,8	—	3,2	—	22,2	26,2	0,1–0,125	0,32
18.	Ipoly (Ipolytölgyes)	41,9	—	11,3	7,8	—	20,6	—	2,1	1,4	—	—	—	—	—	0,7	—	—	—	—	—	6,4	—	—	—	—	—	—	—	—	7,8	11,6	0,1–0,2	0,48
19.	Tisza (Tiszakanyar)	22,6	1,1	12,4	6,5	1,0	9,7	—	—	1,1	—	—	9,7	0,5	0,5	—	—	0,5	—	—	—	10,2	1,1	—	—	—	0,5	—	1,1	3,2	18,3	7,7	0,1–0,2	0,28
20.	Tisza (Tiszalök)	44,4	3,5	13,1	4,2	1,4	9,7	—	—	—	—	—	1,4	1,4	—	—	—	1,4	—	—	—	5,6	1,4	—	—	—	—	—	1,4	—	13,1	15,7	0,1–0,2	0,23
21.	Tisza (Tiszaroff	13,3	1,3	11,3	4,7	2,0	7,3	—	—	0,7	—	—	13,3	0,7	2,7	—	—	0,7	0,7	—	—	8,0	—	—	—	—	—	—	5,3	0,7	27,3	1,2	0,1–0,125	0,10
22.	Tisza (Szolnoktól É-ra)	7,1	2,6	6,2	7,1	1,8	5,3	—	1,3	0,9	—	—	19,0	1,8	0,9	0,4	—	3.6	1,8	—	—	4,9	—	0,4	—	—	2,2	—	3,1	11,9	17,7	1,6	0,1–0,125	0,13
23.	Tisza (Csongrád)	15,0	1,7	8,1	2,9	—	1,7	—	0,6	—	—	—	1,7	0,6	1,2	0,6	—	0,6	0,6	0,6	—	45,0	1,2	—	—	—	0,6	—	1,7	—	15,6	18,0	0,1–0,2	0,18
24.	Tisza (Újszeged)	8,1	5,5	13,1	6,5	2,0	9,5	—	—	2,0	0,5	—	4,0	0,5	2,0	0,5	1,0	8,1	2,5	—	—	17,1	1,0	1,5	—	—	0,5	—	3,0	—	11,1	5,2	0,1–0,125	0,15
25.	Zagyva (Szentlőrinckáta)	6,2	2,1	4,6	4,1	—	8,7	—	1,0	0,5	—	—	0,5	2,1	1,0	—	—	1,5	0,5	0,5	—	42,6	—	—	—	—	1,0	—	2,1	1,0	20,0	5,4	0,1–0,2	0,60
26.	Zagyva (Jászberény)	7,7	0,6	3,8	7,1	—	6,5	—	1,9	1,3	—	—	0,6	1.3	3,3	—	0,6	3,3	—	—	—	37,5	0,6	1,9	—	—	1,3	—	3,3	—	17,4	2,4	0,1–0,2	0,19
27.	Sajó (Sajónémeti)	1,1	4,6	6,8	1,1	5,2	13,9	—	—	2,9	—	—	5,8	1,7	0,5	—	1,1	4,6	1,1	0,5	—	10,4	0,5	0,5	—	—	1,1	—	1,7	2,3	32,6	5,0	0,1–0,125	0,19
28.	Sajó (Szirmabesnyő)	9,4	1,1	2,8	2,3	1,8	12,9	—	—	1,8	—	—	6,3	1,1	—	—	—	1,1	1,8	—	—	32,8	1,1	—	—	—	0,5	—	6,3	0,5	16,4	5,7	0,1–0,2	1,10
28.	Sajó (Sajóőrös)	18,9	1,7	5,7	1,1	0,6	19,4	—	—	—	—	—	9,7	0,6	—	—	0,6	0.6	0,6	—	—	9,7	0,6	—	—	0,6	1,7	0,6	4,5	—	22,8	4,4	0,1–0,2	0,60
30.	Bódva (Edelény)	2,6	—	3,9	0,7	—	12,5	—	—	—	—	—	3,9	1,9	—	—	—	—	0,7	—	—	1,3	0,7	—	—	4,6	—	5,3	29,6	—	32,3	2,1	0,1–0,2	0,47
31.	Hernád (Hernádszurdok)	29,3	2,1	5,7	—	—	15,8	—	—	—	—	—	7,1	0,7	—	—	—	—	—	—	—	6,5	—	—	—	—	3,5	—	2,1	—	27,2	8,7	0,1–0,2	0,45
32.	Bodrog (Felsőberecki)	6,9	0,5	16,2	5,8	1,7	15,0	—	—	0,5	—	0,5	10,4	1,7	1,7	—	0,5	1,7	1,7	—	—	9,9	0,5	0,5	—	—	0,5	—	4,1	—	19,7	1,2	0-1–0,125	0,12
33,	Bodrog (Bodrogkeresztúr)	22,8	3,4	11,0	4,1	—	4,8	—	—	2,2	0,7	—	13,1	0,7	0,7	—	0,7	3,4	—	—	—	12,4	—	—	0,7	—	0,7	—	4,1	—	14,5	1,0	0,1–0,125	0,11
34.	Szamos (Rápolt)	20,0	0,6	14,2	5,9	1,3	6,5	—	—	0,6	—	—	7,1	1,2	1,3	—	—	3,9	0,6	—	—	16,1	1,3	1,3	—	—	1,3	—	2,7	0,6	13,5	13,0	0,1–0,2	0,53
35.	Szamos (Tunyogmatolcs)	10,6	3,8	6,2	3,8	0,6	13,7	—	—	1,3	0,6	—	1,3	0,6	1,3	—	—	1,3	0,6	—	—	13,7	0,6	1,9	—	—	3,1	—	5,0	—	30,0	16,4	0,1–0,125	0,32
36.	Berettyó (Hencida)	10,2	1,8	10,0	18,6	0,6	10,2	—	0,6	1,2	—	—	3,6	2,2	—	—	—	1,8	1,2	—	—	13,0	1,2	2,2	—	—	—	—	4,8	—	16,8	3,4	0,1–0,2	0,36
37.	Sebes Körös (Komádi)	—	2,2	3,8	10,7	1,1	15,3	—	—	1,7	0,5	—	2,2	2,7	2,2	—	1,1	0,5	—	—	—	35,6	0,5	0,5	—	—	—	—	2,2	—	17,5	14,8	0,1–0,125	0,20
38.	Fekete Körös (Sarkad)	10,7	2,4	11,8	8,9	3,6	8,3	—	—	1,1	—	—	4,2	0,6	2,4	1,1	—	1,8	0,6	—	—	10,1	—	0,6	—	—	—	—	2,9	—	28,9	3,0	0.1–0,125	0,16
39.	Fehér Körös (Gyulavári)	13,6	1,8	24,6	14,8	—	11,7	—	—	—	—	—	3,7	0,6	—	—	—	—	0,6	—	—	1,8	—	—	—	—	—	—	3,7	—	19,1	14,0	0,1–0,2	0,49
40.	Hármas Körös (Endrőd)	5,3	4,3	13,4	16,7	2,7	4,3	—	0,5	0,5	—	—	5,9	2,1	2,1	0,5	0,5	2,7	1,6	—	—	13,4	2,1	0,5	—	—	—	—	4,8	1,6	14,5	5,3	0,1–0,125	0,10
41.	Hármas Körös (Kunszentm.)	9,2	3,8	15,5	17,9	7,6	5,4	—	—	1,1	—	—	1,1	0,6	2,2	1,1	0,6	1,1	1,6	0,6	—	4,9	0,6	0,6	—	—	1,6	—	2,2	—	20,7	5,5	0,1–0,125	0,15
42.	Maros (Apátfalva)	10,0	1,6	13,9	8,3	1,1	11,1	0,6	—	0,6	—	—	3,3	0,6	1,1	—	0,6	1,1	1,6	—	—	23,3	2,8	0,6	—	—	1,1	—	0,6	—	16,1	13,6	0,1–0,2	0,55
43.	Maros (Kiszombor)	11,0	1,9	10,2	11,0	5,1	7,0	—	0,6	3,3	—	—	4,5	0,6	1,9	1,9	0,6	4,5	5,1	—	—	8,4	0,6	0,6	0,6	—	2,5	—	1,9	—	16,1	5,9	0,1–0,125	0,24
44.	Maros (Deszk)	4,9	2,9	12,8	10,3	2,5	9,0	—	—	0,9	—	—	8,4	0,9	2,5	—	0,5	4,9	2,5	—	—	5,4	0,9	0,9	—	—	1,9	—	1,9	—	25,1	7,8	0,1–0,125	0,16

* In alluvia of the Danube region dominantly diopside, in alluria of the Tisza region dominantly augite.

the nomenclature of sandy sediments, we apply the size grade elaborated by I. MIHÁLTZ and GY. BÁRDOSSY) [1, 8, 9]. Heavy-mineral compositions have been determined on the basis some 200 grains in the case of major rivers, while on that of about 100 or 150 grains in the case of minor rivers, the examination

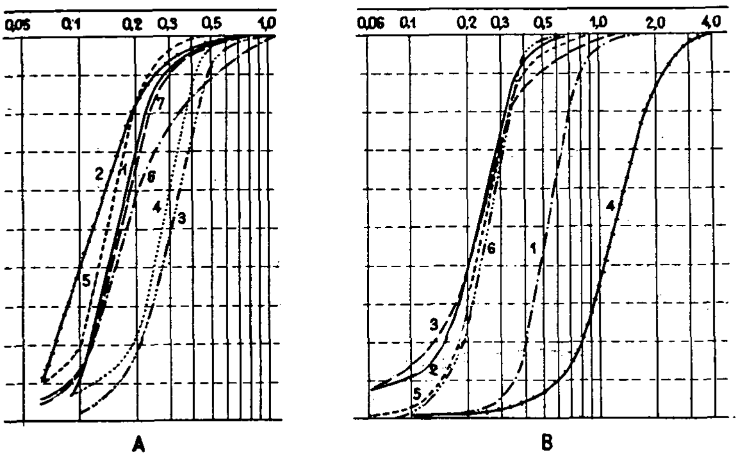

Fig. 2. a
Duna
1. Kisbodak
2. Dunaalmás
3. Vác N.
4. Margit-Isle
5. Dunaföldvár
6. Gerjen
7. Baja

b
Rába
1. Magyarlak
2. Rum
3. Várkesző
4. Rábapatona
Marcal
5. Boba
Mura
6. Murarátka

of such a quantitity of grains already gives a true picture of the composition. [10] The important part played by metamorphic minerals is very characteristic, and it proves that these minerals come from the Alps, *i. e.* from an area consisting of metamorphic rocks.

The quantity of calcite and dolomite is greater, here, as compared to other Danubian samples, at Kisbodak it amounts to 20%, at Dunaalmás to 7,6%, too. This relatively high degree indicates the effect of the NE Limestone Alps, while to the east of this territory, the quantity of the above-mentioned minerals becomes smaller, because of the well-known solubility of carbonate minerals as well as because the Rába river itself does not transport carbonate minerals, therefore the alluvia of the Rába and probably those of its tributaries coming from the north are weakening this character.

Fig. 3. shows the heavy minerals of the Danube sand at Dunaalmás. On the left-hand side, in the middle, it is observable that even the hard cyanite is rounded, which indicates transport from a considerable distance: from the Alps. The light-coloured minerals with uneven fractures are garnets, the almost globular opaque minerals are magnetites. The other dark minerals are weathered or incrustated ones.

The effect of hypersthene-amphibole-andesite and garnet-bearing andesite, andesitic tuff — Börzsöny and Dunazug Mountains — are demonstrable in the Danubian alluvia, too. Later on, we shall see that the tributaries, brooks of this region transport great quantities of alluvia rich in magmatic minerals. Among

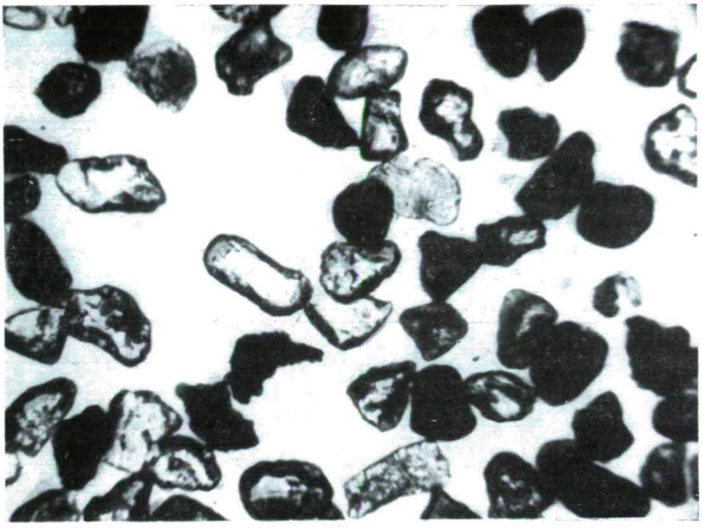

Fig. 3. Heavy minerals of the Danube sand at Dunaalmás, from the 0,1 to 0,125 mm fraction. (Photographs taken by polarizing microscope, nicols, minerals embedded in nitrobenzene).

the above-mentioned Danubian samples, it was only that of Dunaalmás which contained 0,5% of hypersthene, while to the north of Vác the amount of this characteristically magmatic mineral is as high as 9%.

In the rivers of Hungary, there are two types of brown amphibole: the one is a dark variety, rich in iron, the other is more light-coloured and less rich in iron. The ratio expressed in percentage of the two varieties is often characteristic, therefore we have everywhere distinguished the two types.

In *Fig. 4.* (Diagram I), it is shown that from Vác, *i. e.* from the volcanic mountains the quantity of dark-brown amphibole is gradually increasing to Dunaföldvár where it is above 10%. On the other hand, the maximum of light-brown amphiboles, 6,4%, is to be found at Gerjen.

The shift of the maxima of these three minerals coming from volcanic areas, as compared to each other, shows the resistance to weathering of the minerals, too. Hypersthene is the most friable one among them, this is why it occures very scarcely in the drift sands of the region situated between the Danube and the Tisza [11—12].

In *Fig. 5,* in the 0,1 to 0,125 mm fraction of the Danubian sand sampled at Dunaföldvár are discernible, beside the garnet, the dark-brown (dark-shaded columnar minerals) and light-brown (light-shaded columnar minerals) amphiboles. In the sample of Dunaalmás such minerals were not yet observed.

I.

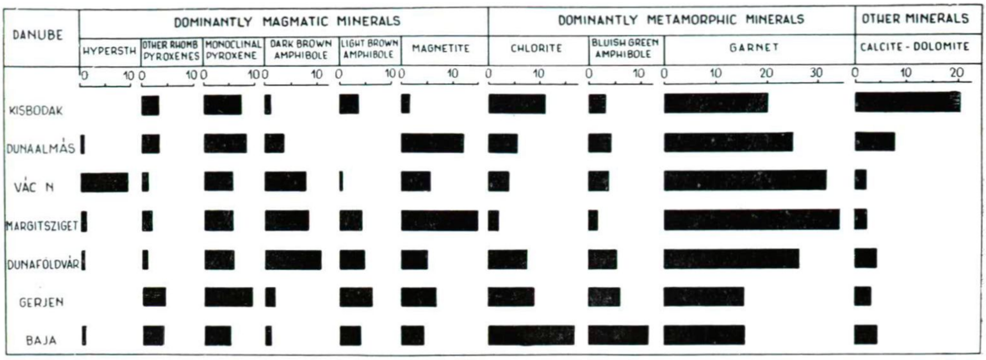

Fig. 4. (Diagram I.) Dominant heavy-mineral sorts in the alluvia of the Danube.

Because of its great specific weight, magnetite reacts the most rapidly to the changes in conditions of deposition, therefore — in the same way as in earlier investigations — we could not point out any regularity concerning the changes in the amount of this mineral.

The amount of garnet is fairly considerable in every sample taken from the Danube, it is varying between 16 and 34%, reaching its maximum in the samples coming from Vác and the Margaret Island. It has been pointed out, by previous examinations, that finer fractions extracted from coarser-grained sand always contained considerable quantities of garnet, and the total amount

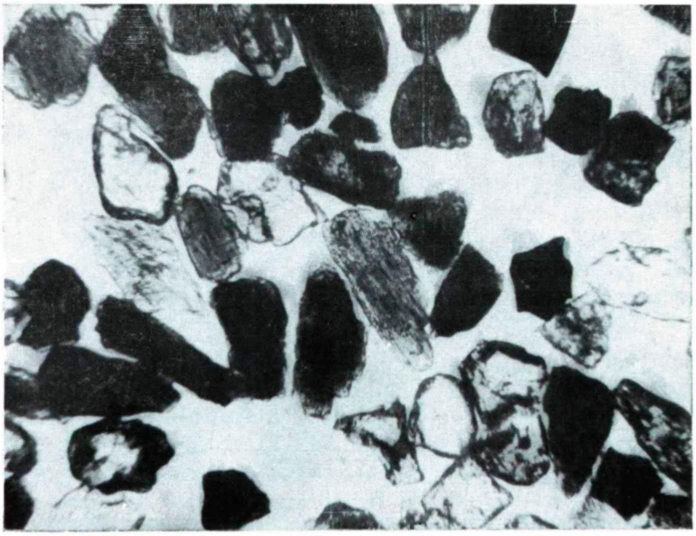

Fig. 5. Heavy minerals of the Danube sand at Dunaföldvár, from the 0,1 to 0,125 mm fraction.

of heavy-minerals in these fractions was always greater, too. [14]. The grain size distributions of samples of Vác and Margaret Island are the coarsest ones, the dominant grain size of the Vác sample being 0,27 mm, that of Margaret Island 0,32 mm. Both samples contain, however, coarser fractions, *i. e.* those above, 0,5 mm. *(Fig. 2, A).* Another, but less important cause of the greater amount of garnet probably is the garnet contents of the andesites of the volcanic mountains.

Towards the southern reach of the Danube in Hungary, on can again demonstrate the admixture more metamorphic mineral. Along this reach the Danube is washing away, at many places, the Pannonian strata where metamorphic minerals are dominant, too [5, 12, 13, 19].

The *Sió,* discharching into the Danube, almost exclusively runs in a Pannonian loess territory, and it transports alluvia rich in metamorphic minerals into the Danube, too. It is especially from Dunaföldvár on that the amount of characteristically metamorphic minerals is increasing, *p. e.* that of the chlorite wich is as high as 16% at Baja. The increased percentage of chlorite may partly be attributed, here, to the fact that in relatively coarser fractions extracted from matters of finer grain size distribution, the amount of micas is always higher than in the finer fractions [14]. Bluish-green amphibole, a very characteristic mineral of the Danubian sediments here amounts to 11%, actinolite-tremolite to 2,8%, disthene to 2%.

It can be thus pointed out that the Danube transports alluvia of metamorphic origin, for the most part, in its reaches in Hungary; in the reach near the Austrian border the amount of calcite and dolomite is considerable, while from the Börzsöny-Dunazug Mountains downstreams the role of magmatic hypersthene and brown amphibole becomes important, too. [25, 26, 27, 28].

In the course of our examinations of heavy-mineral composition, carried out until now, we have found Danubian deposits, in Hungary, in the Great Hungarian Plain, namely between the Danube and the Tisza, where the eolian strata and the fluvial ones below them, to the depth of 500 or 600 metres, are of Danubian origin, and comprise the Quaternary and uppermost Pliocene (Levantine) deposits [16].

The *Rába,* right-hand tributary of the Danube, takes its source in the Eastern Alps, and it thus transports a dominant part of its alluvia from this region. Among the samples examined, coming from the Rába, those of Magyarlak and Rábapatona are coarse sand (0,5 to 2,0 mm) and even gravelly sands (12,0 to 20,0 mm), *i. e.* very coarse-grained, while the samples of Rum and Várkesző consist of medium-grained sand, for the most part (See *Fig. 2, B* and *Fig. 6, Graph II.*).

In the sediments of the Rába it is again the metamorphic character of the minerals which is dominant. In the Table as well as in the graph, monoclinic pyroxenes are to be seen in the column of magmatic minerals. As for their genesis, however, these minerals probably are diopsides of metamorphic origin, all over the catchment area of the Danube. Diopsides can be produced, however either by magmatic or by metamorphic processes, this is why we do not represent them separately. Monoclinic pyroxenes of the Danube Region differ in they lighter colours (except for the alluvia of the Ipoly) from the monoclinic pyroxenes of the catchment area of the Tisza, namely the latter are not diopsides, for the most part.

II.

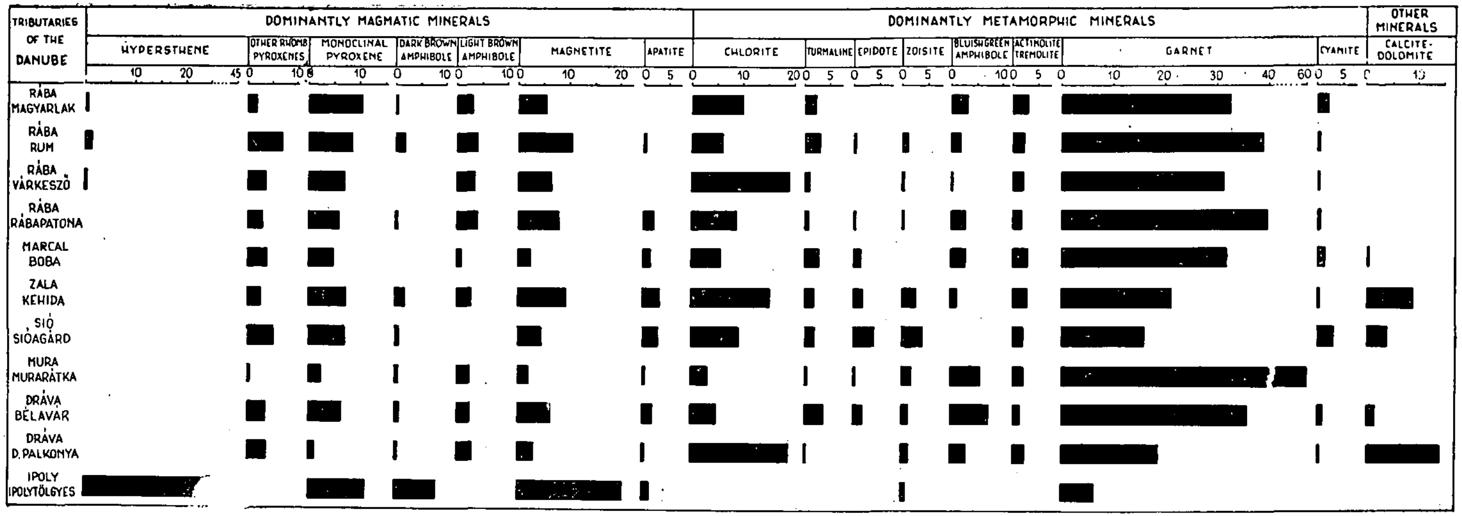

Fig. 6. (Digram II.) Dominant heavy mineral sorts in the alluvia of the tributaries of Danube.

Among magmatic minerals, it is the light-brown amphibole which plays a minor part in the Rába; as for the metamorphic ones, one finds considerable amounts chlorite, tourmaline, actinolite-tremolite and especially garnet, the latter representing more than 30% in each sample. Accordingly, the Rába transports, at all points, almost exclusively metamorphic minerals.

As regards the alluvia of the *Marcal,* discharging into the Rába, heavy-mineral examinations have already been carried out by G. BIDLÓ and E. TÖRÖK, it was only for the sake of completeness that we examined a medium-grained sand sample and found its composition analogous to those observed by previous examinations, with this difference that the amount of olivine was somewhat smaller, that of garnet being somewhat greater in the present sample [2]. In the alluvia of the Marcal the effect of the volcanic rocks of the environment (olivine) is demonstrable, too, nevertheless the alluvia of the Marcal are of metamorphic character, for the most part.

Heavy-mineral examinations of fine-grained sands of the *Zala* river at Kehida and of the *Sió* river at Sióagárd have shown that — as both rivers are running on dominantly Pannonian, loess terrain and the high metamorphic-mineral contents of the Pannonian sediments being known — no other river in Hungary transported alluvia so rich in metamorphic minerals that these two ones. *(Fig. 7,* A and *Fig. 6, Graph II).* In both of them, the part of metamorphic chlorite, tourmaline, epidote, zoisite, actinolite-tremolite, garnet and disthene is very important. The effect of the neighbouring Keszthely Mountains is shown, on the other hand, by the higher amount (8%) of dolomite and calcite in the Zala. [18, 22, 23, 24].

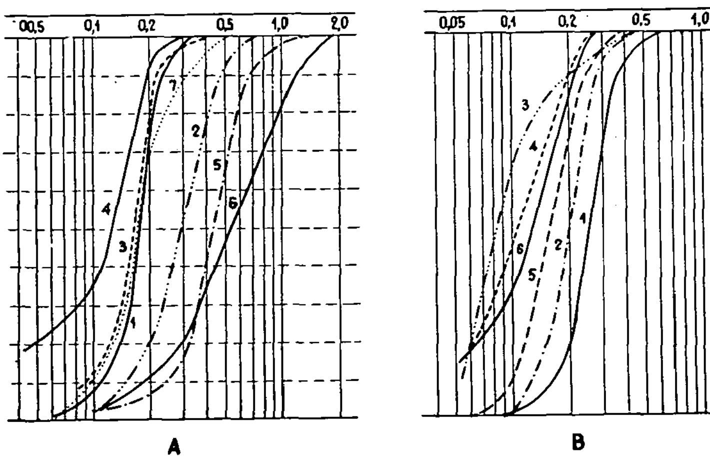

Fig. 7. **a**
Dráva
1. Bélavár
2. Drávapalkonya
Zala
3. Kehida
Sió
4. Sióagárd
Ipoly
5. Ipolytölgyes

b *Tisza*
1. Tiszakanyar
2. Tiszalök
3. Tiszaroff
4. Szolnok N.
5. Csongrád
6. Újszeged
Zagyva
6. Szentlőrinckáta
7. Jászberény

The *Dráva* and the *Mura* carry the dominant part of their respective alluvia from the Alps, too, therefore metamorphic character is again dominant in these sediments. The 0,1 to 0,2 mm fraction of medium-grained Mura sand contains 60% garnet. Such a high amount of garnet was not found in any other river of the country. Beside garnet, bluish-green amphibole (6%) and monoclinic pyroxene (6,6%) are important, too.

As for the composition of the Dráva sand at Bélavár and that of the medium-grained Dráva sand at Drávapalkonya, metamorphic character is still dominant. At Drávapalkonya the amount of calcite is as high as 14%; such a great amount indicates the effect of the Villány Mountains and, partly, that of the Mecsek Mountains (Fekete viz brook).

Fig. 8 shows the heavy minerals of the 0,1 to 0,125 mm fraction of the Drávapalkonya sand. Beside garnets, actinolite-tremolites and chlorites are well observable, too.

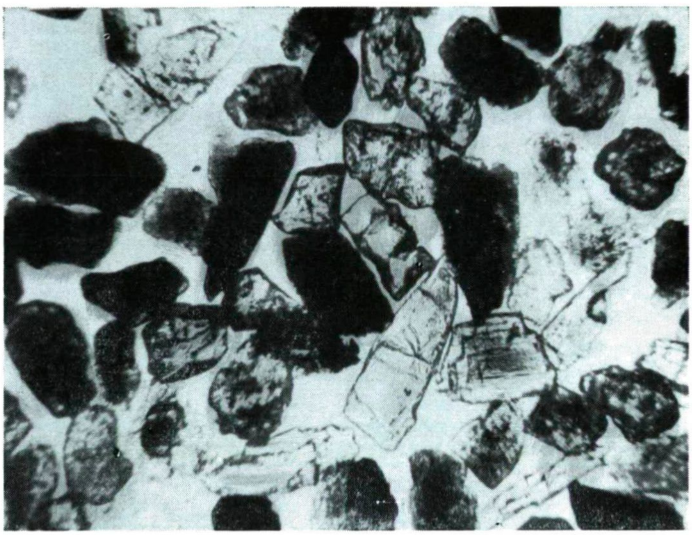

Fig. 8. Heavy minerals of the 0,1 to 0,125 mm fraction of Dráva sand, at Drávapalkonya.

The composition of the alluvia transported by the *Ipoly* are completely different from those of any other Hungarian tributary of the Danube. Minerals of magmatic character are dominant in the medium-grained sand of Ipolytölgyes. This difference is to be seen in *Fig. 6, Graph II.* and *Fig. 9. I. e.* hypersthene (see first column) did not appear in the above-mentioned tributaries of the Danube or it played there but a quite minor part, whereas it amounts to 42% at Ipolytölgyes. Dark-brown amphibole amounts to 8%, magnetite to 2%, biotite to 2%, while one very scarcely finds metamorphic and epigenetic minerals. This mineral association of particularly magmatic character comes from the Börzsöny Mountains.

Fig. 9 shows the heavy minerals of the 0,1 to 0,2 mm fraction of the Ipolytölgyes sample taken from the Ipoly. The amount of hypersthene, with quite idiomorphic crystals is dominant. Opaque inclusions of hypersthene are well observable, too. Beside hypersthene, one finds monoclinic pyroxenes and garnets.

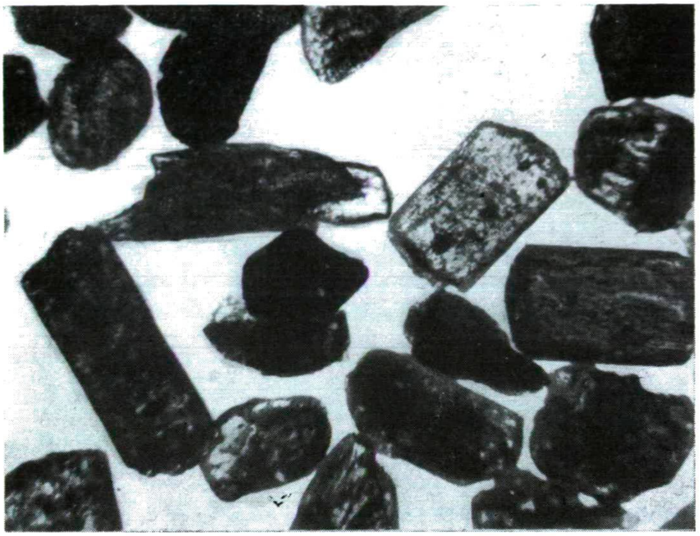

Fig. 9. Heavy minerals of the 0,1 to 0,2 mm fraction of Ipoly sand, at Ipolytölgyes.

Thus the dominant character of the alluvia of the Hungarian tributaries of the Danube — except for the Ipoly — is metamorphic. In this peculiarity, the sediments of the Danube Region differ from those of the Tisza Region (Tisza and its tributaries). The Ipoly, however, shows a composition completely analogous to the rivers of the Tisza Region.

The Danube and its Hungarian tributaries carry an important part of their alluvia from territories situated outside of the Carpathian Basin, *i. e.* from the Alps, while the alluvia of the rivers of the Tisza region come from the territory surrounded by the Carpathians. Inside the arch of the NE and E Carpathians, consisting of sandstones for the most part, there runs a Tertiary volcanic chain, thus the respective catchment areas are more different from each other as for their geology. Differences between the alluvia transported by the rivers will be more considerable, too, and they depend on the circumstance whether the rivers spring more or less near to the margins of the basins, or perhaps at the arch of the Carpathians.

THE TISZA REGION
(The Tisza and its tributaries)

As for the Tisza river, it can be pointed out that its tributaries produce important changes in the composition of the alluvia of the Tisza, therefore, in its course, the changes will be greater than in the case of the Danube. This feature is well illustrated *p. e.* by the changes in percentage of the hypersthene, plotted in the first column of the graph *(Fig. 10, Graph III)*.

The most remote medium-grained sand-sample examined comes from Tiszakanyár *(Fig. 7, B)*. As for its composition, one finds a characteristically magmatic heavy-mineral association, as well as in other samples taken from the Tisza. The amount of hypersthene is 23%, that of monoclinic pyroxene

III.

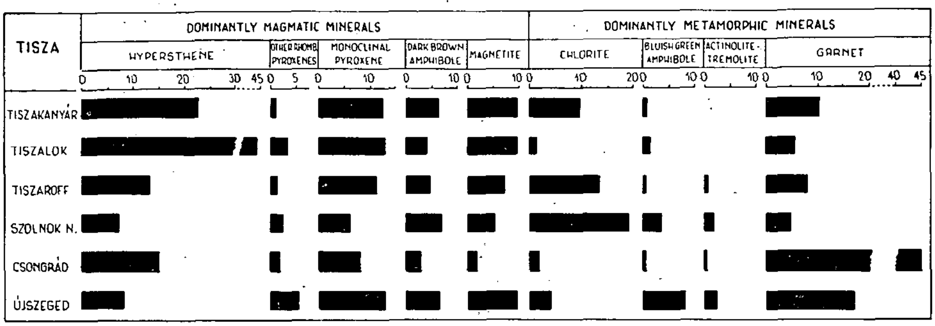

Fig. 10. (Diagram III.) Dominant heavy mineral sorts in the alluvia of the Tisza.

13%, dark-brown amphibole 6,5%, Minerals of metamorphic character play a less important part.

In the likewise medium-grained sand sample of Tiszalök, the role of hypersthene is even more considerable, it amounts to 44%. This higher amount of hypersthene, as compared to the previous samples, may be explained by the fact that the Hernád meanwhile joins the Tisza and the former carries considerable quantities of hypersthene. Other important minerals appear in similar amounts.

In *Fig. 11*, heavy minerals of the 0,1 to 0,2 mm fraction of the Tisza sand and Tiszalök can be seen. It is observable that the hypersthenes are still quite idiomorphic, here.

In the not quite well-sorted fine-grained sand sample of Tiszaroff as well as in that of Szolnok, the role of magmatic minerals is similarly dominant. It is observable that as far as Szolnok the amount of hypersthene decreases to 7%, probably because of increasing decay. The amount of micas is increasing, *i. e.* the 0,1 to 0,125 mm fraction represents a coarser part of the fine-grained sand, the part played by micas is always major in these fraction.

In the fine-grained and medium-grained sands of Csongrád, the amount of hypersthene and garnet is again greater. This change indicates the effect of the Zagyva and that of the Körös.

In *Fig. 12*, it is to be seen on the Tisza sand sampled at Csongrád that the hypersthenes are already rounded, which is an effect of a long transport. Beside hypersthenes, garnets are observable in major amounts.

In the fine-grained sand sample of Újszeged, it is the admixture of the alluvia of the Maros which is already demonstrable. There we find the above-mentioned minerals and, beside them, somewhat greater amounts of epidote, bluish-green amphibole and actinolite-tremolite.

On the basis of the above-mentioned data, the alluvia of the Tisza are well distinguishable from those of the Duna Region. The association of mag-

matic minerals of the Tisza is always characteristic, especially because of the higher amounts of hypersthene, dark-brown amphibole and dark-coloured monoclinic pyroxene (dominantly augit).

In the compositon of the tributaries of the Tisza, going from the W to the E — in the gravelly sand (terrace?) coming from Szentlőrinckáta and in the fine-grained sand of Jászberény, both taken from the *Zagyva* — it can be pointed out that the amount of garnet is very important, beside the general magmatic character of the Tisza Region *(Fig. 7, A* and *Fig. 13, Graph IV).*

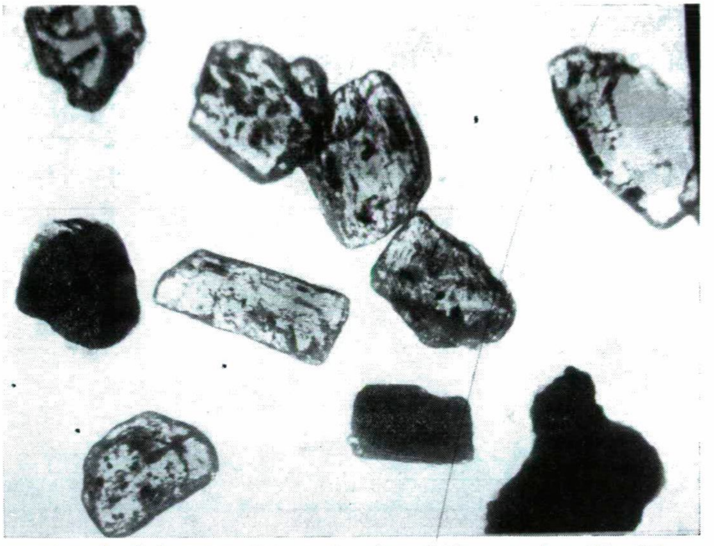

Fig. 11. Heavy minerals of the 0,1 to 0,2 mm fraction of Tisza sand, at Tiszalök.

Fig. 12. Heavy minerals of the 0,1 to 0,2 mm fraction of Tisza sand, at Csongrád.

IV.

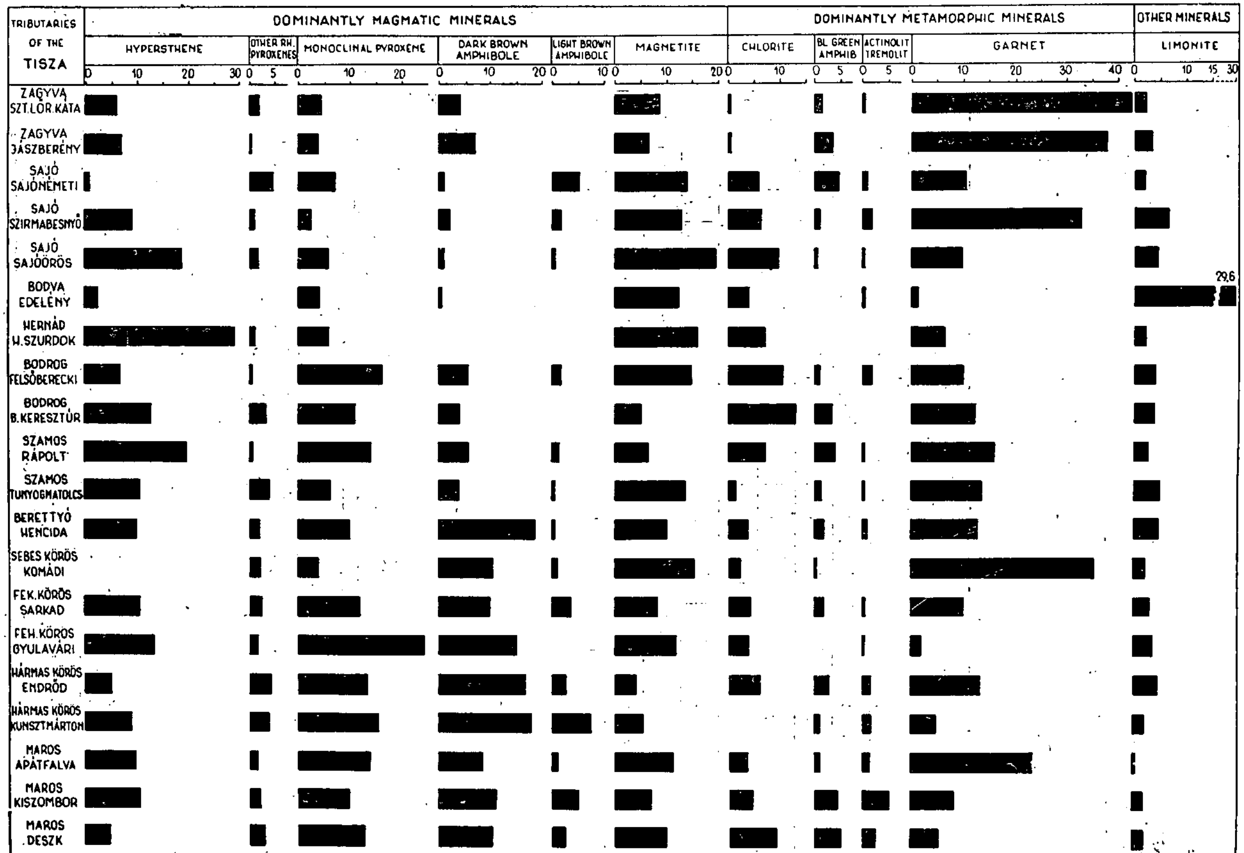

Fig. 13. (Diagram IV.) Dominant heavy mineral sorts in the alluvia of the tributaries of the Tisza.

In the 0,1 to 0,2 mm fraction, extracted from the coarser- and finer-grained sands, it amounts to 37 or 42%, too. The genesis of such a high amount of garnet will be pointed out by further investigations. It is quite probable, however, that it is transported from the Pannonian and Post-Pannonian strata, by the Zagyva and its tributaries. Between the Zagyva and the Tisza, in the environment of Pély and Kisköre, we have found sediments of similar character and heavy-mineral composition, as far as the previously determined lower boundary of the Pleistocene, *i. e.* to 200 m [4, 15, 22].

The *Sajó* and some of its tributaries take their sources in the Slovakian Ore Mountains, consisting of crystalline schists. This feature appears in the fine-grained sand sample coming from Sajónémeti, near the border *(Fig. 14, A)*. The amount of hypersthene and dark-brown amphibole is as low as 1%,

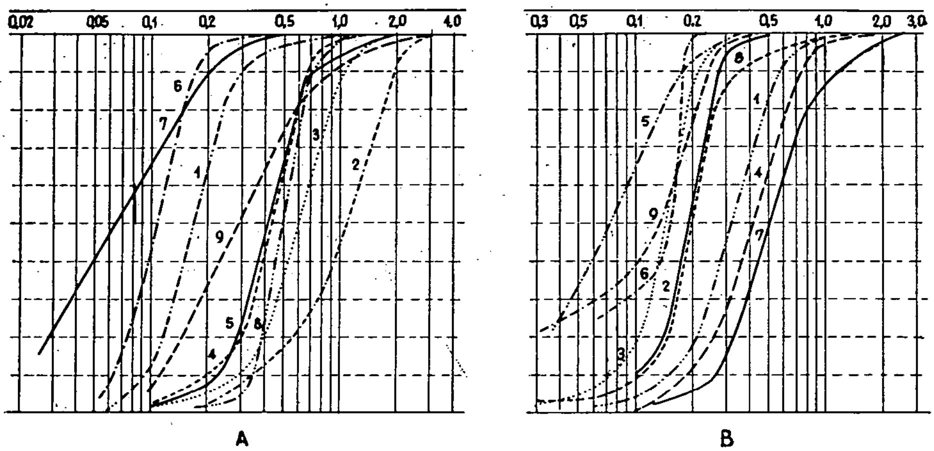

Fig. 14. **a** *Sajó*
1. Sajónémeti
2. Szirmabesnyő
3. Sajóörös
Bodva
4. Edelény
Hernád
5. Hernádszurdok
Bodrog
6. Felsőberecki
7. Bodrogkeresztúr
Szamos
Rápolt
9. Tunyogmatolcs

b *Berettyó*
1. Hencida
Sebes Körös
2. Komádi
Fekete Körös
3. Sarkad
Fehér Körös
4. Gyulavári
Hármas Körös
5. Endrőd
6. Kunszentmárton
Maros
7. Apátfalva
8. Kiszombor
9. Deszk

while in the sample of Szirmabesenyő the amount of hypersthene increases to 9,4%, that of dark-brown amphibole to 2,3%, and before meeting the Tisza, at Sajóörs, the amount of hypersthene is as high as 19%. Thus the magmatic character becomes dominant after having taken up the rivers and brooks springing from eruptive terrains. The effect of carbonate-bearing mountains is demonstrable by the increase in calcite and dolomite.

The above-mentioned features are well illustrated in *Fig. 15* where the heavy-minerals of the 0,1 to 0,125 mm sand fraction coming from Sajónémeti are still metamorphic ones for the most part, and in *Fig. 16* where hypersthene becomes dominant in the 0,1 to 0,2 mm fraction of the sample of Sajóörs, situated at the mouth of the Sajó.

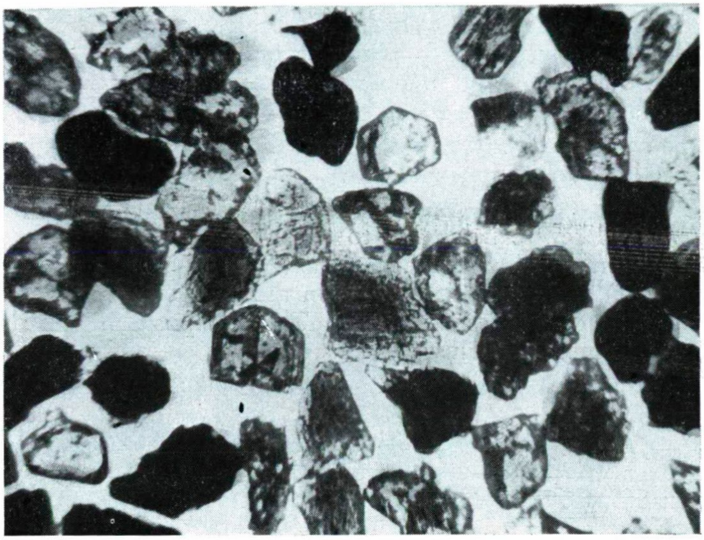

Fig. 15. Heavy minerals of the 0,1 to 0,125 mm fraction of Sajó sand, at Sajónémeti.

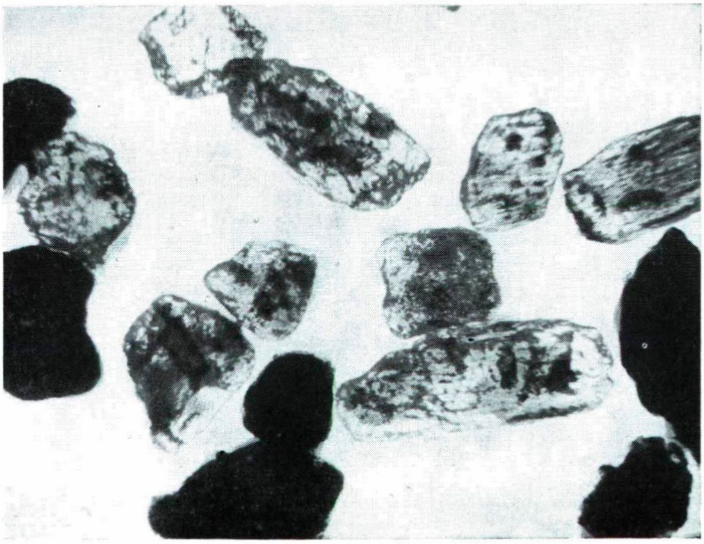

Fig. 16. Heavy minerals of the 0,1 to 0,2 mm fraction of Sajó sand, at Sajóörös.

In the medium-grained sand sample taken at Edelény from the *Bódva* flowing into the Sajó, the number of the occuring mineral species is small, because of the smallness of the catchment area. As for the minerals determining the genesis of the alluvia, one finds 4,6% glaucophane and 5,3% anhydrite. Glaucophane and anhydrite — transported by the Bódva — are demonstrable in small quantities in the Sajó, as far as Sajóörs, too. The limonite contents of alluvia of the Bódva are also very considerable, it amounts to 32%. It is probably upon the effect of this phenomenon and that of the surrounding territories, that the amount of limonite becomes higher in the Sajó, from the mouth of the Bódva downstreams.

The same can be seen in *Fig. 17, i. e.* in the middle of the figure one finds anhydrites of low refraction and, around them, weathered minerals and limonite grains.

The *Hernád,* likewise belonging to the catchment area of the Sajó transports in preponderant amounts hypersthene (29%), monoclinic pyroxene (6%) (dominantly augit) and magnetite (16%) in the 0,1 to 0,2 mm fraction of the medium-grained sand at Hernádszurdok. This composition already indicates the effect of the Zemplén Mountains.

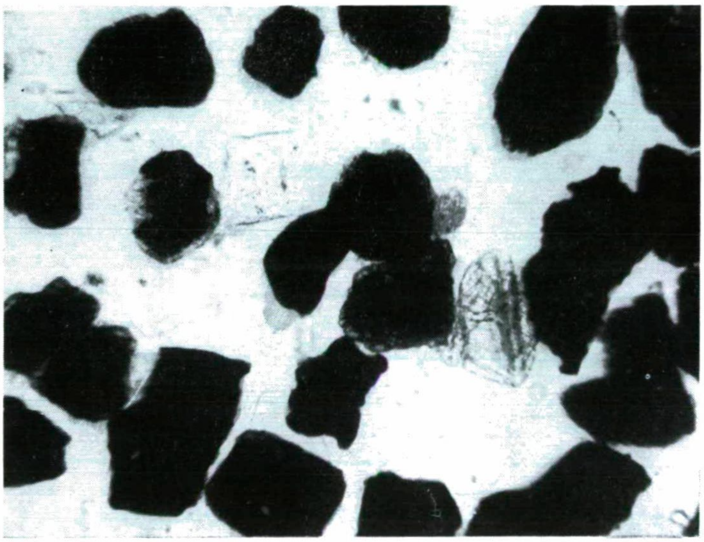

Fig. 17. Heavy minerals of the Bodva sand at Edelény, from the 0,1 to 0,2 mm fraction.

It is characteristic of the Sajó and its tributaries examined, that their weathered-mineral contents are quite considerable. They vary from 23 to 32%, with the exception of the very coarse sample of Szirmabesnyő.

In the alluvia of the *Bodrog,* the association of magmatic minerals is fairly rich, too, the percentage of magmatic minerals is even increasing from the border to the mouth of the river: at Felsőberecki, in the fine-grained sand, hypersthene amounts to 7%, monoclinic pyroxene to 16%, while at Bodrogkeresztúr, likewise in fine-grained sand, hypersthene already amounts to 23% and monoclinic pyroxene to 11%. It is thus evident that monoclinic pyroxene there plays an important part, too. The case of the other tributaries of the Tisza — to be treated hereafter — is analogous. On the Bodrog, in like manner as on the Hernád, it is the effect of the Zemplén Mountains which is demonstrable.

In the *Szamos,* namely in the medium-grained sand coming from Rápolt and in the medium- and coarse-grained sand taken at Tunyogmatolcs, the magmatic character was dominant, the hypersthene contents being also very considerable: it amounted to 10 or 20%. The role of monoclinic pyroxenes is important, too. The alluvia of the Szamos touching the Transylvanian Basin are somewhat richer in heavy-mineral species, this feature is due to the more varied geology of the area. [22].

In the Hernád, Bodrog and Szamos, the amount of hypersthene is always much higher than that of dark-brown amphibole. On the other hand, in the medium-grained sand sample taken at Hencida, from the *Berettyó,* it is to be seen that the amount of hypersthene is as high as 10%, *i. e.* greater than in the former. The graph also shows that the role of hypersthene and monoclinic pyroxene, dominantly augit, is important in the Hernád, Bodrog and Szamos, while the association of dark-brown amphibole, hypersthene and monoclinic pyroxene (dominantly augit) plays a more important part in the branches of the Körös and in the Maros.

In the sample taken at Komádi from the *Sebes Körös* no hypersthene was found, while dark-brown amphibole amounts to 10%. According to P. Szabó this sample should represent a Danubian alluvium. Szabó has considered the ratio of pyroxenes and amphiboles as the most important difference between the respective alluvia of the Tisza and Danube Regions. According to him, the dominance of pyroxenes represents Tisza sediments, that of ampiboles indicating Danubian ones. It is thus evident that dark-brown ampibole may be preponderant as compared to pyroxene, even in sediments of the Tisza Region. The alluvia of the Sebes Körös, however, can be distinguished from the Danubian sediments, as, in the former, the amount of tourmaline and epidote is higher, that of bluish-green amphibole hornblende being extremely low, while actinolite-tremolite and calcite-dolomite are completeley lacking. The Sebes Körös is also characterized by its considerable garnet contents amounting to 35% in the medium-grained sand.

In *Fig. 18,* garnets of the sand of the Sebes Körös are to be seen. The high-degree corrosion of these minerals is well observable.

In the sample taken from the *Fekete Körös,* at Sarkad, the amount of hypersthene exceeds that of dark-brown amphibole, but their ratio still remains almost identic. As compared to the Sebes Körös, the amount of garnet is lower; 10% in the samples we have examined. In the sample taken from the *Fehér Körös,* at Gyulavár, minerals and the occuring mineral species are similar to the former, as the geology of the respective catchment areas is almost identic.

In the samples taken from the *Hármas Körös* (Triple Körös = from the junction of the three branches), at Endrőd and Kunszentmárton, we find all the minerals that were demonstrable in its tributaries. The general feature, *i. e.* the predominance of dark-brown amphibole over hypersthene, remains. Monoclinic pyroxene occurs in a considerable amount, too.

As for the *Maros*, examinations of heavy-mineral composition have been carried out on samples taken at Apátfalva, Kiszombor, and Deszk; this order represents, at the same time, finer and finer sandy sediments. The Maros runs on a territory of varied geology, hence its alluvia are richer in mineral species.

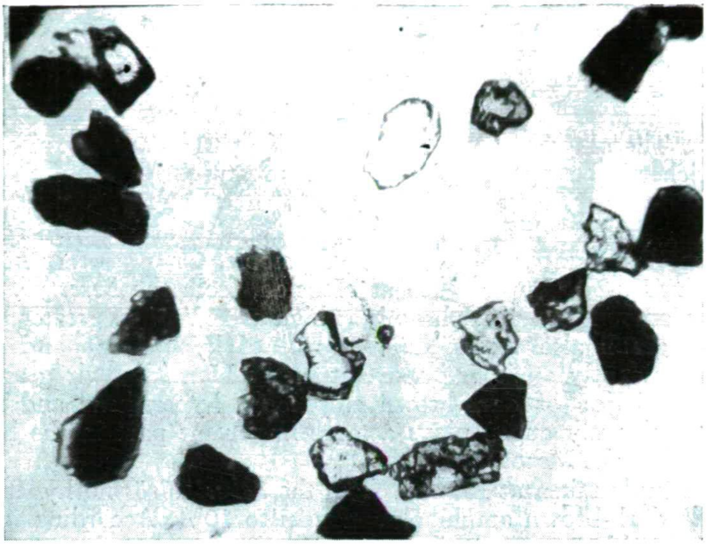

Fig. 18. Heavy minerals of the 0,1 to 0,125 mm fraction of Sebes Körös sand.

The role of hypersthene, monoclinic pyroxene (dominantly augit), dark-brown and light-brown amphiboles is quite important. Among the important metamorphic minerals, bluish-green amphibole, actinolite-tremolite are occuring in considerable amounts.

Fig. 19 shows also that dark-brown amphiboles, hypersthenes and garnets are to be seen beside each other.

On the basis of the examinations of heavy-mineral composition carried out so far, it can be pointed out that the alluvia of the Tisza from Csongrád down-streams, those of the Hármas Körös and Maros are not distinguishable from each other with absolute certainty. There occur the same minerals, in almost similar percentages, and minor differences observed in the course of the investigations are perhaps due to differences in grain-size distribution. Further, detailed investigations are still necessary in order to distinguish the above-mentioned sediments with certainty.

In the course of the examinations carried out so far, sediments of the Tisza-Region type have been found in the above mentioned surroundings of Pély and Kisköre to the depth of 200 m, and at Hajdunánás to 120 m, likewise to the lower limit of the Pleistocene. Along the intensely sinking Körös rivers, the same formations were found to the depth of 800 m already examined, at Makó to 170 m, at Szentes to 240 m, at Szeged to 175 m. At the two latter places, *i. e.* in the line of the Tisza, the sediments of the Tisza Region show a digitiform make-up, and they are wedging out between the sediments of the Danube Region [9, 11, 12, 13, 15, 16, 20, 21].

The above-described results of the examinations carried out on recent, fluvial, sandy sediments of known genesis reflect for the most part the lithology

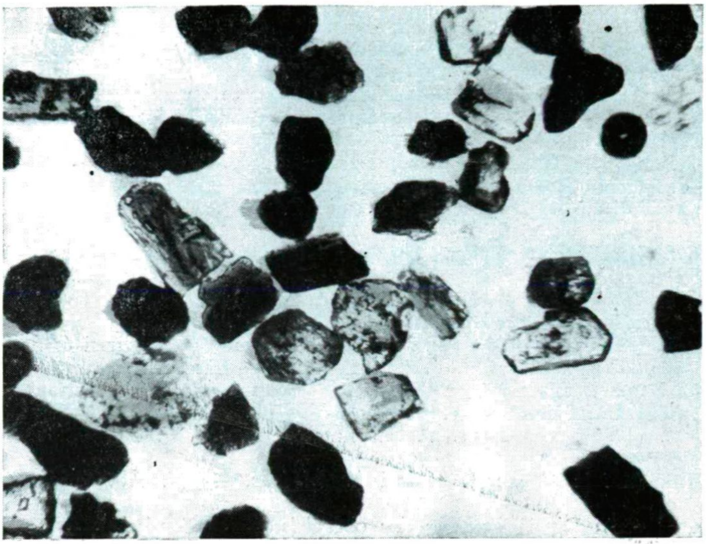

Fig. 19. Heavy minerals of the 0,1 to 0,125 mm fraction of Maros sand, at Deszk.

of the catchment areas of the respective rivers, thus the composition of a sand of unknown (fossil) origin may indicate the provenance of the same.

Further on, it is most desirable that similar examinations of alluvia should be carried out on every important river belonging to the centripetal river-system of the Carpathian Basin, besides the Hungarian rivers and reaches.

REFERENCES

[1] Bárdossy, Gy. (1961): Problems of the nomenclature of sedimentary rocks. — Bulletin of the Hungarian Geological Society. *XCI.* 44—64.

[2] Bidló, G.—Török, E. (1963): Mineralogische Untersuchung der Geschiebe des Marcal-Flusses. — Zeitschrift der Ungarischen Geologischen Gesellschaft. *XCIII.* 244—247.

[3] Herrmann, M. (1956): Micromineralogical investigations on some Pannonian (Lower Pliocene) sands from the Kisalföld and Dunántúl, Western Hungary. — Bulletin of the Hungarian Geological Society. *LXXXVI.* 59—66.

[4] Jaskó, S. (1947): Erosion and Sedimentation in the Hungarian Basin During the Kainozoic Era. — Bulletin of the Hungarian Geological Society. *LXXVII.* 26—38.

[5] Kriván, P. (1955): La Division climatologique du pléistocene en Europe Centrale. — Annales de l'Institut Geologique de Hongrie. *XLIII.* 363—503.

[6] Lengyel, E. (1931): Die Mineralogische Zusamensetzung verschiedener Sande vom Alföld. — Zeitschrift der Ungarischen Geologischen Gesellschaft. *LXI.* 192—199.

[7] Mezősi, J.—Donáth, É. (1951): The Mineralogical and Chemical Investigation of the Floating Material of the Maros and Tisza. — Acta Mineralogica, Petrographica. *V.* 38—57.

[8] MIHÁLTZ, I. (1952): Détermination sur place de la gandeur des grains de sable. — Bulletin de la Société Géologique de Hongrie. *LXXXII*. 57—57.
[9] MIHÁLTZ, I. (1951): Le Levé Géologique de la partie Méridionale de L'Entre-Deux-Fleuves Danube—Tisza. — Rapport Annuel de L'Institut Géologique de Hongrie sur L'Année. 53—61.
[10] MOLNÁR, B. (1959): Fehlermöglichkeiten der statistischen Schwermineral-Analyse. — Zeitschrift der Ungarischen Geologischen Gesellschaft. *LXXXIX*. 294—297.
[11] MOLNÁR, B. (1961): Die Verbreitung der äolischen Bildungen an der Oberfläche und untertags im Zwischenstromland von Donau und Theiss. — Zeitschrift der Ungarischen Geologischen Gesellschaft. *XCI*. 300—315.
[12] MOLNÁR, B. (1962): Sedimentpetrographische Untersuchung in Pliozänen und Pleistozänen Ablagerungen in Süden des Ungarischen Tieflandes. — Acta Mineralogica-Petrographica. *XV*. 43—51.
[13] MOLNÁR, B. (1963): Gliederung der pliozänen und pleistozänen Ablagerungen des südlichen Teiles der Grossen Ungarischen Tiefebene auf Grund der Zusammensetzung der Schwermineralien. — Zeitschrift der Ungarischen Geologischen Gesellschaft. *XCIII*. 97—107.
[14] MOLNÁR, B. (1963): Untersuchung über den Zusammenhang der Sandkorngrösse und der Schwermineralzusammensetzung. — Acta Mineralogica-Petrographica. *XVI*. 25—33.
[15] MOLNÁR, B. (1963): Sedimentgeologische Untersuchungen in pliozänen und pleistozänen Ablagerungen im Osten des Ungarischen Tieflandes. — (Manuscript)
[16] MOLNÁR, B. (1963): Adatok a Duna—Tisza köze fiatal harmadkori és negyedkori rétegeinek tagolásához nehézásvány-összetétel alapján. — (Kézirat)
[17] RAVASZNÉ BARANYI L. (1959): Az Ellend 1. Földtani alapfúrás kőzettani vizsgálata. — M. Áll. Föld. Int. Évi Jel. 439—461.
[18] SHWÁB, M. (1960): Fonyód 1. távlati kutatófúrás. — M. Áll. Földt. Int. Évi Jel. 291—309.
[19] SHWÁB, M. (1960): Győre 1. távlati kutatófúrás. — M. Áll. Földt. Int. Évi Jel. 323—335.
[20] SZABÓ, P. (1955): Die Entstehung der oberpleistozänen Sandschichten zwischen Donau und Theiss im Lichte ihrer mineralogischen Zusammensetzung. Zeitschrift der Ungarischen Geologischen Gesellschaft. *LXXXV*. 442—456.
[21] SZABÓ, P. (1956): A szegedi városi fürdői mélyfúrás homokrétegeinek nehézásványvizsgálata. — (Kézirat)
[22] SZÁDECZKY-KARDOSS, E. (1932): Flussschotteranalyse und Abtragungsgebiet. — Soproni Bányamérnöki és Erdőmérnöki Főiskola Közleményeiből. *IV*.
[23] SZÁDECZKY-KARDOSS, E. (1938): Geologie der Rumpfungarländische Kleinen Tiefebene.
[24] SZTRÓKAY, K. (1935): Sedimentpetrographische Studien am pontischen Sand des Zala-Tales. — Zeitschrift der Ungarischen Geologischen Gesellschaft. *LXV*. 281—291.
[25] VENDL, A. (1913): Über den Sand der Csepel-Insel. — Zeitschrift der Ungarischen Geologischen Gesellschaft. *XLIII*. 375—389.
[26] VENDL, A. (1923): A Duna budapesti homokjának ásványai és kémiai összetétele. Anyagvizsgálók Közlönye.
[27] VENDL, A.—TAKÁCS, T.—FÖLDVÁRI, A. (1935): Studien über den Löss der Umgebung von Budapest. — Mathematischer und Naturwissenschaftlicher Anzeiger. *LII*. 713—787.
[28] VENDL, A.—TAKÁCS, T.—FÖLDVÁRI, A. (1936): Über den Löss Börzsöny-Gebirges. — Mathematischer und Naturwissenschaftlicher Anzeiger. *LIV*. 177—206.